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SUBSTRATE TEMPERATURE CONTROL DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a device for controlling the substrate temperature by heating or cooling a substrate in operations of processing substrates such as semiconductor wafers or liquid crystal panels.

2. Description of the Related Art

In a semiconductor device manufacturing process, operations of heating or cooling wafers are frequently performed. For example, when applying resist on a wafer, the wafer is heated so as to remove moisture and resist solvent and then cooled. Typically, a substrate temperature control device employed for heating/cooling substrates such as semiconductor wafers comprises a stage with a flat upper surface on which the substrate is placed, and a heat source device for heating and/or cooling is arranged within or below the stage. For a heating device there is generally employed an electric heating wire or infra-red lamp or working fluid etc., while for a cooling device working fluid is generally employed. In particular working fluid is most widely employed. In temperature control devices of this type, fluid piping is frequently employed to convey the working fluid and, typically, elongate fluid piping that meanders within the interior of the stage is provided and the working fluid flows within this meandering piping. Also, in some devices, a wide passage extending over the entire region of the stage are formed within the stage and the working fluid flows in the wide passage.

The performance factor that is firstly required in a substrate temperature control device is what is generally called good thermal response, rapidity of heating/cooling or good temperature controllability. This is the capability for attaining the desired temperature rapidly. For this purpose, it is important to make the heat capacity of the stage small. Secondly required is the factor called thermal uniformity. This is the capability of controlling the entire substrate to the same temperature without temperature unevenness. However, when a working fluid is employed, there is the problem that the temperature difference is produced between locations on the upstream side and locations on the downstream side of the flow path, since the temperature of the working fluid changes due to heat exchange with the stage whilst the working fluid is flowing through the stage. A further problem is that the temperature difference is produced between the upper and lower surfaces of the stage, so that the stage is subjected to thermal deformation in the vertical direction (for example, the central region may be raised or lowered with respect to the peripheral region). Therefore the gap between the stage and the substrate varies with location, causing the substrate temperature to be uneven. Further important factors that are demanded are, thirdly, low cost, fourthly, a high degree of safety, and fifthly, ease of manufacture. In general, the manufacture of fluid piping is troublesome, and pressure losses are large due to the meandering of the piping.

Consequently, an object of the present invention is to provide a substrate temperature control device with good thermal response and low cost.

A further object of the present invention is to provide a substrate temperature control device with good thermal response and good thermal uniformity.

Also a further object of the present invention is to provide a substrate temperature control device of good thermal response, good thermal uniformity, and low cost.

Yet a further object of the present invention is to provide a substrate temperature control device of good thermal uniformity.

Also a further object of the present invention is to provide a substrate temperature control device of good thermal uniformity and low cost.

Yet a further object of the present invention is to provide a substrate temperature control device of good thermal response, good thermal uniformity, low cost and a high degree of safety.

Also yet a further object of the present invention is to provide a substrate temperature control device of good thermal uniformity and ease of manufacture.

SUMMARY OF THE INVENTION

A substrate temperature control device according to a first aspect of the present invention comprises a flat plate-shaped stage having a main surface facing a substrate, wherein this stage has a flat plate-shaped container, and this container comprises: a cavity for flow of working fluid;

a working fluid inlet and outlet; and turbulence structure for creating turbulence of said working fluid within the cavity. With this device, since working fluid flows in turbulent fashion within the container cavity, excellent thermal uniformity and thermal response are obtained. The term "main surface" denotes the upper surface of the stage in the case where the substrate is placed on the stage. However, in cases where the substrate is made to adhere by suction using a vacuum etc., the stage may assume various different attitudes. To include such cases, the term "main surface" therefore denotes the stage surface on the side where the substrate is arranged.

In a preferred embodiment, a plurality of ribs joining the wall on the side of the main face and the wall on the opposite side of the container are provided so that the fluid is stirred by means of these ribs. Also, these ribs prevent deformation of the container by fluid pressure, by increasing the mechanical strength of the substrate of the container; this also contributes to improving thermal uniformity. Furthermore, in a preferred embodiment, thermal uniformity and thermal response are improved by positively generating further turbulence by injecting the working fluid into the cavity in the form of a jet, or by creating swirling flow.

Also, in a preferred embodiment, the inlet and outlet are arranged such that the inlet is provided in the peripheral region of the container and the outlet is provided in the central region, or this arrangement is reversed, or the inlet and outlet are respectively provided in the peripheral region of the container, thereby making the temperature distribution of

the working fluid within the container as far as possible uniform. This also contributes to improving thermal uniformity. Furthermore, care may be taken, by providing the inlet facing a direction parallel to the wall on the main face side of the container in the peripheral wall of the container, or by arranging the container peripheral region provided with the inlet in a position extending out beyond the periphery of the substrate, to ensure that the strong thermal action of the working fluid when it first flows in is not locally concentrated; this also improves thermal uniformity.

Also, in a preferred embodiment, sheet-shaped heaters are provided on one or both of the main face and opposite side face of the container, and heating is performed by means of these sheet-shaped heaters while cooling is performed by means of the working fluid. With a stage of such a simple construction, the thermal capacity can be designed to be fairly small, so excellent thermal response can be obtained. Also, if it is arranged to employ the working fluid solely for cooling, the working fluid system can be simplified, and so made considerably cheaper.

A substrate temperature control device according to a second aspect of the present invention comprises a flat plate-shaped stage having a main surface facing a substrate, wherein this stage has a flat plate-shaped container, and this container comprises: a cavity for flow of working fluid; and a working fluid inlet and outlet; the inlet and outlet being arranged such that the inlet is provided in a peripheral region of the container, while the outlet is provided in a central region of the container; or the inlet and the outlet are provided in the opposite manner; or the inlet and outlet

are both provided in a peripheral region of the container. With such a device, the working fluid flows radially from the periphery of the container to the center or in the opposite direction, or in a back and forth direction, so the temperature distribution of the working fluid becomes quite uniform, improving thermal uniformity. In particular in an arrangement wherein there are inlets in a plurality of locations, the flows from these plurality of inlets mutually intermingle, creating turbulence, so even better thermal uniformity and thermal response can be expected.

Furthermore, if turbulence structure as described above is provided, thermal response is improved and thermal uniformity is also further improved. Also, if sheet-shaped heaters are provided on one or both of the main face and face on the opposite side of the container, heating being performed by these heaters, while only cooling is performed by the working fluid, much lower costs can be achieved.

A substrate temperature control device according to a third aspect of the present invention comprises a flat plate-shaped stage having a main surface facing a substrate, wherein this stage has a flat plate-shaped container and this container comprises: a cavity for flow of working fluid, and within the cavity a plurality of ribs connecting the wall on the side of the main face of the container and the wall on the opposite side. With such a substrate temperature control device, the mechanical strength of the container is increased by the ribs, so working fluid at high pressure can be supplied into the container so as to create a high-speed flow of working fluid, and turbulence is created by the ribs, so excellent thermal response

and thermal uniformity can be obtained. With this device also, by adopting a combination of turbulence structure and/or inlet/outlet arrangement and/or heater etc. as already described, the benefits of further improvement of performance or lowering of costs can be achieved.

A substrate temperature control device according to a fourth aspect of the present invention comprises a flat plate-shaped stage having a main surface facing a substrate, wherein said stage comprises a flat plate-shaped container having in its interior a cavity for flow of working fluid and sheet-shaped heaters arranged on both the main face and face on the opposite side of this container. With this substrate temperature control device, since a construction is adopted which is thermally and mechanically symmetrical as between the main face and opposite face of the stage, distortion or flexure of the stage due to thermal expansion is reduced, thereby improving thermal uniformity; also with this device, by adopting the various expedients described above, the benefits of a further improvement in performance and lowering of costs can be achieved.

A substrate temperature control device according to a fifth aspect of the present invention comprises a stage for carrying a substrate, this stage comprising a container having in its interior a flow path that extends in a region directly below the substrate. It is also provided with an inlet in a peripheral region of this flow path whereby a working fluid is made to flow into the flow path. With this substrate temperature control device, inflow of working fluid into the flow path within the stage takes place from a plurality of locations at the periphery, so the direction of working fluid

flow within the flow path becomes complex instead of in a single simple direction. The result is that temperature changes of the working fluid produced by heat exchange with the stage become inconspicuous, improving thermal uniformity.

Not just inlets but also working fluid outlets may be provided in the peripheral region of the flow path. In particular if a plurality of outlets are provided in the peripheral region, this is beneficial in improving thermal uniformity in the same way as the advantages of providing a plurality of inlets in the peripheral region. In a preferred embodiment, a plurality of inlets and a plurality of outlets are arranged alternately along the flow path periphery. By this means, temperature differences between upstream and downstream become even more inconspicuous, improving thermal uniformity.

The flow path can be divided into a plurality of small flow paths, each flow path and each inlet being connected such that the working fluid flows in mutually opposite directions in adjacent small flow paths. If this is done, local temperature differences are moderated by heat exchange between the small flow paths, thereby improving thermal uniformity. As a specific example, in an embodiment, the flow path is divided into a plurality of outgoing flow paths whereby working fluid flows from the peripheral region towards the central region and a plurality of return flow paths whereby working fluid flows from the central region towards the peripheral region, the outgoing flow paths and return flow paths being arranged alternately. Also, in another embodiment, the flow path is

divided into a plurality of elongate small flow paths running parallel to each other, the working fluid flowing in mutually opposite directions in adjacent small flow paths.

Also, two containers may be arranged one on top of the other, the direction of flow of working fluid within the two containers being made mutually opposite. In this way also, mutual temperature unevenness of the two containers is canceled out, thereby improving thermal uniformity.

It is also possible to arrange a large number of fins within the flow passage, or to arrange a cotton-like or gauze-like fiber body therein. By this means, the flow of working fluid within the flow path is disrupted, thereby moderating temperature unevenness and so improving thermal uniformity; improvement in efficiency of the heat exchange may also be expected due to the turbulence effect.

A plate-shaped heat pipe may also be joined to the upper surface of the container. The high heat transfer action of the heat pipe contributes to improvement of thermal uniformity. Also, electric heating wire heaters may be stuck onto one or both of the upper surface and under-surface of the container. In particular if heaters are stuck onto both faces of the container, temperature differences between the upper and lower faces of the container become small, so strain in the vertical direction due to thermal expansion is reduced; this also contributes to improvement in thermal uniformity.

A substrate temperature control device according to a sixth aspect of the present invention comprises a stage for carrying a substrate, this stage

comprising a container having in its interior a cavity that extends in a region directly below the substrate, the container comprising an inlet provided in a peripheral region of the container whereby a working fluid is supplied to the cavity, an outlet provided in a peripheral region of the container whereby working fluid is discharged from the cavity, and one or a plurality of guide walls that partition the cavity, bent flow paths being formed within the cavity by the guide walls.

In a preferred embodiment, a large number of fins or ribs are arranged within the cavity.

In another preferred embodiment, the guide walls are provided with one or a plurality of bypass holes. These bypass holes may be provided in the vicinity of the bending locations of said plurality of flow paths.

In another preferred embodiment, the working fluid flows with approximately uniform speed along the entire length of the bent flow paths formed by the guide walls.

In a yet a further preferred embodiment, the guide walls cause the working fluid from said inlet to circulate through said cavity after being guided to the vicinity of said outlet. For example, the guide walls may guide the flow at the center of the cavity towards both sides or guide the flow at the periphery of the cavity towards the center of the cavity.

In yet a further preferred embodiment, the container is provided with an inlet and outlet at practically the same location.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of a stage portion of a substrate temperature control device according to a first embodiment of the present invention;

Figure 2 is a plan cross-sectional view along the line A - A of Figure 1;

Figure 3 is a lateral cross-sectional view of a stage portion of a substrate temperature control device according to a second embodiment of the present invention;

Figure 4 is a plan cross-sectional view along the line A - A of Figure 3;

Figure 5 is a lateral cross-sectional view of a stage portion of a temperature control device according to a third embodiment of the present invention;

Figure 6 is a plan cross-sectional view along the line A - A of Figure 5;

Figure 7 is a lateral cross-sectional view of a stage portion of a temperature control device according to a fourth embodiment of the present invention;

Figure 8 is a plan cross-sectional view along the line A - A of Figure 7 ;

Figure 9 is a lateral cross-sectional view of a stage portion of a temperature control device according to a fifth embodiment of the present invention;

Figure 10 is a plan cross-sectional view along the line A - A of Figure 9;

Figure 11 is a lateral cross-sectional view of a stage portion of a temperature control device according to a sixth embodiment of the present invention;

Figure 12 is a plan cross-sectional view of a container of a stage portion of a substrate temperature control device according to a seventh embodiment of the present invention;

Figure 13 is a view showing the cross-sectional shape of a jet aperture;

Figure 14 is a plan cross-sectional view sectioned along a horizontal plane of the stage of a substrate temperature control device according to an eighth embodiment of the present invention;

Figure 15(A) is a cross section of view along the line A - A of Figure 14 and Figure 15(B) is a cross-sectional view along the line B - B of Figure 14;

Figure 16 is a plan cross-sectional view illustrating in detail a guide fin 231, with sector-shaped passages 209A, 209B shown to a larger scale;

Figure 17 is a plan view sectioned along a horizontal plane of the stage of a substrate temperature control device according to a ninth embodiment of the present invention;

Figure 18 is a cross-sectional view along the line C - C of Figure 17;

Figure 19 is a plan view sectioned along a horizontal plane of the stage of a substrate temperature control device according to a tenth embodiment of the present invention;

Figure 20 is a perspective view illustrating the stage of a substrate temperature control device according to an eleventh embodiment of the present invention;

Figure 21 is a perspective view illustrating the stage of a substrate temperature control device according to a twelfth embodiment of the present invention;

Figure 22 is a perspective view illustrating the stage of a substrate temperature control device according to a thirteenth embodiment of the present invention;

Figure 23 is a plan cross-sectional view of two containers constituting a substrate temperature control device according to a fourteenth embodiment of the present invention;

Figure 24 is a cross-sectional view of a stage along the line D - D of Figure 23;

Figure 25 is a cross-sectional view illustrating a substrate temperature control device according to a fifteenth embodiment of the present invention;

Figure 26 is a perspective view of a container constituting a stage of a substrate temperature control device according to a sixteenth embodiment of the present invention;

Figure 27 is a cross-sectional view of a container along the line A - A of Figure 26;

Figure 28 is a plan cross-sectional view of a container provided with a bypass hole in each guide wall;

Figure 29 is a plan cross-sectional view of a container in which the shape of guide wall 409c is altered;

Figure 30 is a plan cross-sectional view of a container in which the shapes of guide walls 409a and 409b of Figure 29 are altered;

Figure 31 is a plan cross-sectional view of a container constituting a stage of a substrate temperature control device according to a seventeenth embodiment of the present invention;

Figure 32 is a plan cross-sectional view of a container in the case where the number, shape and arrangement of the guide walls of the container of Figure 31 are altered;

Figure 33 is a cross-sectional view of a container constituting a stage of a substrate temperature control device according to an eighteenth embodiment of the present invention; and

Figure 34 is a cross sectional view of a container constituting a stage of a substrate temperature control device according to a nineteenth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments to which the present invention is applied are described below with reference to the drawings.

Figure 1 is a lateral cross-sectional view of a stage portion of a substrate temperature control device according to an embodiment of the present invention, and Figure 2 is a plan cross-sectional view along the line A - A of Figure 1. It should be noted that, in order to facilitate understanding of the drawings, the dimensional ratios of the various parts in the Figures are different from those of the actual devices. This also applies to the other drawings, to be described later.

Stage 1 consists, as a whole, of a thin plate-shaped body of circular shape. A circular substrate, typically, a semiconductor wafer 3, is placed on its flat upper surface. On the upper surface of stage 1, there are provided small projections 5 of the same height (for example 0.1 mm) at several locations. These projections 5 support wafer 3, preventing contact with wafer 3 (they are provided in order to prevent contamination of wafer 3 from stage 1). In general terms, stage 1 comprises the following two layers. The first layer consists of a thin film heater (electric heating wire heater laminated or embedded in an insulating film by a printing wiring technique) 7 in the form of a circular sheet constituting the upper surface of stage 1. The second layer is a thin disc-shaped container 9 for flow of working fluid therein; thin film heater 7 is stuck on to the upper surface of container 9.

Container 9 is provided with a cavity 11 for the flow of working fluid throughout its interior, and is constructed using thin sheets of material of good thermal conductivity such as aluminum or copper alloy, by for example the method of brazing thin plates at their peripheries, or another

method. In the bottom wall of this container 9, there are provided inlets 17 at a plurality of peripheral locations for the supply of working fluid into cavity 11, and an outlet 19 at a single location in the middle for the discharge of working fluid from cavity 11; fluid supply pipes 13 are coupled at the locations of inlets 17 and a fluid discharge pipe 15 is coupled at the location of outlet 19. (It should be noted that, in an arrangement opposite to this, it would be possible to make the central hole 19 an inlet, the peripheral holes 17 being made to be outlets; however, from the point of view of thermal uniformity, it is believed that the arrangement, as in this embodiment, wherein inflow takes place from the peripheral region and outflow takes place from the central region is preferable.) Ribs 21 are erected connecting the bottom wall and the ceiling wall at a large number of locations within cavity 11. An object of these ribs 21 is to increase the mechanical strength of container 1, in particular to prevent swelling of container 9 caused by the pressure of the working fluid. By this means excellent thermal response and thermal uniformity can be achieved by supplying working fluid at high pressure and causing it to flow at high speed. A second object of ribs 21 is to improve the efficiency of heat exchange and to achieve good thermal uniformity, by the creation of turbulent flow by disrupting the flow of working fluid within cavity 11. On account of these objects and constructional aspects, it is preferable to make ribs 21 also of material, such as aluminum or copper alloy, of good thermal conductivity and such that joining processing such as brazing can easily be performed. As the working fluid, for example, water, ethylene

glycol, propylene glycol, "GALDEN" (Registered Trade Mark) or "FLUORINERT" (Registered Trade Mark) etc. may be employed. Cavity 11 is basically of the hermetically sealed type with no communication with the atmosphere, so that the working fluid can flow therein in a condition completely filling cavity 11. However, cavity 11 could be of an open type communicating with the atmosphere so that the working fluid flows therethrough in a form in which it is mixed with air or in the form of a spray.

Container 9 is chiefly employed for cooling a wafer 3 by passing cooling (for example normal temperature) working fluid into cavity 11. Heating of wafer 3 is performed by thin-film heater 7. Of course, it would be possible to employ this positively for heating by passing high-temperature working fluid into container 9. However, from the point of view of keeping costs low and ease of ensuring safety, it is preferable not to use positive heating of the working fluid (in particular heating in the high-temperature region of 100 °C or 200 °C). The first reason is that, although the working fluid circulation system is basically one of the most expensive elements, in the case of cooling, no other suitable substitute means is available, so a working fluid system has to be employed; however, in the case of heating, by substituting an inexpensive electric heating wire heater, an expensive fluid heating device can be eliminated from the working fluid system, thereby achieving a considerable reduction in costs. The second reason is that, although, when high-temperature fluid of 100 °C or 200 °C is flowing in the working fluid system, strict safety measures

are necessary, if only cooling working fluid is flowing therein, strict safety measures are unnecessary, so some lowering of costs can be expected.

With this embodiment, the advantages of excellent thermal response, good thermal uniformity and low cost, as mentioned above, can be obtained. The first reason why excellent thermal response can be achieved is that the heat capacity of stage 1 can be made small. Specifically, since stage 1 is of a simple construction consisting of container 9 and thin-film heater 7, practically all of its heat capacity is represented by that of container 9. Although in the drawings the walls of container 9 and its internal cavity 11 are fairly thick, in fact, both of these can be made extremely thin, enabling quite small heat capacity to be achieved. A high heat exchange rate can be maintained by raising the flow speed of the working fluid in proportion as cavity 11 is made thinner, without lowering the flow rate. The second reason is that the heat exchange rate of the working fluid is raised due to turbulent flow produced by the action of ribs 21 and by the mutual intermingling of the flows from the plurality of inlets 17, as shown by the arrows in Figure 2. A third reason is that a large heat exchange rate is obtained since the presence of ribs 21 makes container 9 rigid so that working fluid supplied thereto under high pressure can flow at high speed; as a result, exchange of working fluid within container 9 takes place rapidly and the turbulence becomes even fiercer. The first reason whereby good thermal uniformity can be achieved is that unevenness of temperature distribution is eliminated by the turbulent flow produced by ribs 21. A second reason is that the working

fluid is made to flow at high speed, so exchange of working fluid within container 9 occurs rapidly and turbulence also becomes more severe, reducing unevenness of temperature.

Figure 3 is a lateral cross-sectional view of a stage of the second embodiment and Figure 4 is a plan cross-sectional view of this stage along the line A - A of Figure 3. Elements which are functionally identical with those of Figure 1 and Figure 2 are given the same reference symbols. This also applies in the other drawings, to be described later.

This embodiment has the following two characteristics which are improved from the embodiment described above illustrated in Figure 1 and 2. The first characteristic is that a thin-film heater 35 of the same size and same heat capacity as thin-film heater 7 of the upper surface is stuck on to the lower surface of container 33, not just its upper surface. As a rule, upper and lower thin-film heaters 7 and 35 are used concurrently. In this way, a roughly vertically symmetrical construction of stage 31 in thermal and mechanical terms is obtained, so distortion or flexure of the stage produced by thermal expansion during heating and cooling is suppressed. If distortion or flexure of stage 31 occurs due to thermal expansion, the gap length between wafer 3 and stage 31 (in the condition where the upper surface of stage 31 is flat, the height of projections 5 is fixed at for example 0.1 mm) becomes different at different locations, giving rise to non-uniformity of the temperature distribution of wafer 3 (for example if the gap length differs by 0.1 mm, this results in a temperature difference of

about 40 K). Preventing distortion or flexure of stage 31 therefore makes a considerable contribution to improving thermal uniformity.

A second characteristic is that container 33 has a larger external diameter than that of wafer 3 so that it extends peripherally outwards of wafer 3, and inlets 17 for working fluid are provided in the bottom wall of an outermost annular peripheral region 37 of this extending portion. This annular peripheral region 37 may be constructed of the same material (for example aluminum or copper alloy etc.) as the other portions of container 33, but, from the point of view of the thermal action effect, described below, it is preferable that it should be constructed of a material of poor thermal conductivity, such as for example ceramics. The direction of flow of working fluid flowing from inlets 17 of peripheral region 37 is bent when it strikes the ceiling wall of this peripheral region 37, so that it flows towards the central region. Whereas, in the previous embodiment illustrated in Figure 1, there was the risk that temperature non-uniformity of wafer 3 might be caused by the portion of the ceiling wall struck by the working fluid from inlets 17 being excessively subjected to the local thermal action of the fluid, with this embodiment, since the ceiling wall that is struck by the working fluid from inlets 17 is in a location that is fairly remote from the wafer 3 and its thermal conductivity is poor, the effect on the temperature of wafer 3 is much smaller. Consequently, even better thermal uniformity is obtained.

Figure 5 is a lateral cross-sectional view of a stage of the third embodiment. Figure 6 is a plan cross-sectional view of this stage along the line A - A of Figure 5.

With this embodiment, in addition to the construction of container 33 of the second embodiment illustrated in Figure 3 and 4, container 53 of stage 51 is further provided with an annular partition 55 that partitions cavity 11 into a portion within peripheral region 37 and a portion nearer the central region than peripheral region 37. This partition 55 is provided with a large number (in the drawing there are only 10, but there could be more than this) of jet apertures 59 for converting working fluid flowing into peripheral region 37 into a jet, directed towards the central region. Partition 55 also may be made of the same material as the major part of container 53 (for example aluminum or copper alloy etc.), but, in order to reduce thermal effects, may be constructed of material of poor thermal conductivity, such as ceramics. As shown in Figure 6, the jets in respectively different directions from the large number of jet apertures 59 have considerable force, so more vigorous intermingling and mixture of the working fluid occurs than in the previous embodiments, and turbulence becomes fierce, so a further improvement in thermal uniformity and thermal response may be expected.

Figure 7 is a lateral cross-sectional view of a stage according to a fourth embodiment. Figure 8 is a plan cross-sectional view of this stage along the line A - A of Figure 7.

In this embodiment, a large number (in the Figure, there are only 12, but there could be more) of jet apertures 67 are provided in the peripheral wall of container 63 of stage 61, and feed pipes 13 are coupled thereto, so that jets of working fluid are ejected in respectively different directions within cavity 11 from this large number of jet apertures 67. Just as in the case of the embodiment illustrated in Figure 5 and 6, excellent thermal uniformity and thermal response can be expected.

Figure 9 is a cross-sectional view of a stage according to a fifth embodiment. Figure 10 is a plan cross-sectional view of this stage along the line A - A of Figure 9.

This embodiment is arranged such that working fluid flows from the central region of cavity 11 within container 73 of stage 71 towards the peripheral direction. A fluid inlet 75 is provided in the middle of the bottom wall of container 73; in cavity 11 there is provided an annular partition 77 surrounding a region corresponding to this inlet hole 75. In this partition 77 there are formed a large number of jet apertures 79 for ejecting the working fluid flowing in from inlet hole 75 in the form of jets towards the peripheral direction in radial fashion. Also, the peripheral region 81 on the outermost peripheral side of container 73 is in a position extending outwards from wafer 3, and an annular flow path whereby fluid can flow easily without ribs 21 is formed within this peripheral region 81. Partition 77 and/or peripheral region 81 may be of the same material as the other parts of container 73 (for example aluminum or copper alloy etc.), but, in order to reduce thermal effects, are preferably constructed of

material of poor thermal conductivity, such as ceramics. As shown by the arrows in Figure 10, the working fluid is ejected in the form of jets in respectively different directions within cavity 11 from a large number of central jet apertures 79, and flows through the interior of cavity 11 mutually intermingling and forming a fierce turbulence due to collision with ribs 21, until it finally flows out to discharge pipes 85 through the peripheral region 81. In this embodiment also, excellent thermal response and thermal uniformity can be expected.

Figure 11 is a plan cross-sectional view of the container of a stage according to a sixth embodiment.

This embodiment is a modification of the embodiment illustrated in Figures 7 and 8, in which the directions of the jet apertures 67 are inclined towards the tangential direction of the periphery, so that the jets of working fluid from jet apertures 67 form a swirling flow in the circumferential direction within cavity 11. In the other embodiments also, a similar swirling flow could be formed by inclining the directions of inlets 17 or jet apertures 59, 79 towards the peripheral tangential direction. By means of this swirling flow, turbulence is even more easily generated, so further improvement in thermal response and thermal uniformity may be expected.

Figure 12 is a plan cross-sectional view of a container of a stage according to a seventh embodiment.

Within container 103 of stage 101, there are provided annular flow passages 107 for discharge of fluid, arranged at the peripheral region of

cavity 11 on the other side of a partition 105 and positioned directly below the wafer; further peripheral to these, on the other side of a partition 109, there are provided annular fluid passages 111 for the supply of fluid. In the bottom wall of inner discharge fluid passages 107, there are provided fluid outlets 19 in a plurality of locations. At a plurality of locations of inner partition 105 of these passages 107, there are provided suction apertures 115 for suction of fluid within cavity 11 into passage 107. Fluid inlets 17 are provided at a plurality of locations in the bottom wall of outer fluid supply passages 111. Jet apertures 119 for injecting working fluid into cavity 11 are formed at a plurality of locations of partition 109 on the inside of these passages 111 through connecting pipes 117 therefrom, passing through the inner partition 105.

As shown by the arrows in the drawing, jets of working fluid are vigorously injected towards the central region of the cavity from the plurality of jet apertures 119 at the peripheral region of the cavity. Also, working fluid is guided towards suction apertures 115 and discharged from the central region of the cavity in the flow direction towards the peripheral region. In this embodiment also, excellent thermal response and thermal uniformity are obtained. It should be noted that it could be arranged for supply and discharge of fluid to be effected in the opposite manner to that described above, namely, for fluid to be supplied from inner passages 107 and to be discharged from outer passages 111.

Incidentally, in the embodiments illustrated in Figures 6, 8, 10, 11, and 12, the shape of jet apertures 59, 67, 79, 119 could be made flared at

the outlet as in the case of jet aperture 121 illustrated in cross-section in Figure 13. If such a jet aperture 121 is employed, the jet flow that is ejected therefrom spreads out effectively in radial fashion within the cavity, and intermingling of the jet flows from the plurality of jet apertures is even more effective, so this is believed to be beneficial in improving thermal uniformity and thermal response.

Figure 14 is a plan cross-sectional view sectioned along a horizontal plane of the stage of a substrate temperature control device according to an eighth embodiment of the present invention. Figure 15(A) and (B) are cross-sectional views along the line A - A and B - B of Figure 14.

The stage 201 of this substrate temperature control device has, overall, a flat disc shape and, as shown in Figure 15, a substrate to be treated, for example a semiconductor wafer 205 is placed on top of its upper surface 203. Three or more small projections 207 that support semiconductor wafer 205 are provided on the upper surface 203 of the stage, so that semiconductor wafer 205 is separated by a gap of fixed width from the upper surface 203 of the stage. Stage 201 is constituted as a container having in its interior a cavity 209 which extends by more than the region directly below semiconductor wafer 205, the cavity 209 therein being employed as a flow path for flow of the working fluid. This cavity (flow path) 209 is divided into a large number (for example 18) sector-shaped small flow paths 209A, 209B, by means of a large number (for example 18) of partitions 213 that are arranged along a radius from the peripheral side wall 211 of stage 201 towards the central region. These

sector-shaped flow paths 209A, 209B are of two types; one type of sector-shaped flow path 209A functions as an outgoing path for the flow of working fluid from the peripheral region of stage 201 towards the central region (hereinbelow these are called sector-shaped outgoing flow paths 209A), while the other type of small flow paths 209B function as return paths for the flow of working fluid in the opposite direction (hereinbelow these are called sector-shaped return flow paths 209B). Sector-shaped outgoing flow paths 209A and sector-shaped return flow paths 209B are arranged alternately. All of sector-shaped flow paths 209A, 209B are open in the central region (tip), where they are connected by a common central flow path 209C. A support pillar 216 is erected at the central position within central flow path 209C i.e. at a central position within stage 201.

On the under-surface 217 of stage 201, two annular flow paths 219, 221 are joined in a concentric arrangement, along the periphery of the stage in its peripheral region. The outer annular flow path 219 serves to supply working fluid into stage 201(it will hereinbelow be referred to as annular supply flow path 219); it is connected with a supply pipe 223 that supplies working fluid from the outside, and is linked, through inlet holes 227 at the peripheral region of each flow path 209A, to all of the sector-shaped outgoing flow paths 209A within stage 201. Inner annular flow paths 221 serve to discharge working fluid from within stage 201 (they will hereinbelow be referred to as annular discharge paths 221) and are connected with discharge pipes 225 that discharge working fluid to the outside and are also linked through outlet holes 229 at the periphery of

each flow path 209B to all of the sector-shaped return flow paths 209B within stage 201. Inlet holes 227 and outlet holes 229 are arranged alternately along the entire periphery of outgoing flow paths 209A and return flow paths 209B.

Here and there within all of the sector-shaped flow paths 209A, 209B (although, by way of example, or only one sector-shaped outgoing flow path 209A and one sector-shaped return flow path 209B are illustrated in Figure 14), there are erected a plurality of guide fins (or ribs) 231 in order to cause the working fluid to flow smoothly along the entire surfaces of each flow path 209A, or 209B and to perform satisfactory heat exchange with the working fluid. Figure 16 shows the guide fins 231 in detail, with the sector-shaped flow paths 209A, 209B shown to a larger scale. As shown in Figure 16, these guide fins 231 are of several types: for example, there are fins 231A extending parallel to partition 213 so as to make the flow as a whole follow the radial direction; fins 231B provided at intervals on the central line of sector-shaped flow paths 209A, 209B in order to separate the flow on the central line to left and right; fins 231C provided facing inlet holes 227 in order to separate the flow issuing from inlet holes 227 into left and right; and fins 231D provided facing outlet holes 229 in order to direct the flow towards outlet holes 231.

Stage 201 described above may be constructed using material of good thermal conductivity, such as aluminum or copper alloy.

In a stage 201 constructed as above, as shown by the arrows in the single sector-shaped outgoing flow paths 209A and single sector-shaped

return flow path 209B which are shown by way of example in Figure 14, working fluid enters nine sector-shaped outgoing flow paths 209A from nine inlet holes 227 provided in the stage peripheral region, flows from the peripheral region to the central region through these outgoing flow paths 209A, then collects in the central flow path 209C, whence it is branched into nine return flow paths 209B, then flows from the central region to the peripheral region through these return flow paths 209B to issue outside the stage from nine outlet holes 229 in the stage peripheral region. In this process, the temperature of the working fluid changes, due to heat exchange being performed between the working fluid and stage 201. However, since both working fluid inlet holes 227 and outlet holes 229 are positioned at the peripheral region of stage 201 and the working fluid flows in reciprocal fashion in the radial direction due to the alternate arrangement of a large number (in this example, nine) of outgoing flow paths 209A and return flow paths 209B, excellent equalization of the temperature of stage 201 as a whole is achieved, with local temperature differences such as temperature differences between the peripheral region and central region of stage 201 and temperature differences between outgoing flow paths 209A and return flow paths 209B being moderated. In particular, the region where best temperature equalization is achieved is the inner region of stage 201 rather than the annular discharge paths 221, so it is preferable to design the diameter of stage 201 sufficiently larger than the diameter of semiconductor wafer 205, so that semiconductor wafer 205 is placed above this inner region.

Figure 17 is a plan cross-sectional view wherein a stage of a substrate temperature control device according to a ninth embodiment of the present invention is sectioned along a horizontal plane. Figure 18 is a cross sectional view along the line C - C of Figure 17.

Stage 241 has, overall, a flat disc shape, and, as shown in Figure 18, a substrate to be treated, for example a semiconductor wafer 245 is placed on the upper surface 243 thereof. On the upper surface 243 of the stage, there are provided three or more small projections 247 that support a semiconductor wafer 245, so that semiconductor wafer 245 is separated from the upper surface 243 of the stage by a gap of fixed width.

Stage 241 is constituted as a container having in its interior a cavity 249 that extends further than the region directly below semiconductor wafer 245; cavity 249 therein is employed as a flow path for the flow of working fluid. This cavity (flow path) 249 is divided by an annular wall 253 having a diameter somewhat smaller than that of side wall 251 of the peripheral region of the stage and arranged concentric with side wall 251 into an annular flow path outside this annular wall 253 (hereinbelow called the outer annular flow path) 249C and inner circular flow path; this inner circular flow path is further divided, by a large number of partitions 255 that are arranged mutually parallel, into a large number of elongate small flow paths 249A and 249B. These elongate small flow paths 249A, 249B are of two types: one type of small flow paths 249A serve for the passage of working fluid in the downwards direction in the Figure (hereinbelow these will be called descending flow paths 249A), while the

other type of small flow paths 249B serve for flow of working fluid upwards in the Figure (hereinbelow these will be termed ascending flow paths 249B). The descending flow paths 249A and ascending flow paths 249B are arranged alternately.

To the under-surface 257 of stage 241 is joined an annular flow path 259, along a position directly below outer annular flow path 249C. This annular flow path 259 has the function of supplying working fluid into stage 241 (it is hereinbelow termed annular supply path 259), and is connected with two supply pipes 263 that supply working fluid from the outside, and is linked to outer annular flow path 249C through a large number of inlet holes 267 provided with practically equal pitch in the bottom of outer annular flow path 249C. To the under-surface 257 of the stage there is also joined a further annular flow path 261 in a position adjacent annular supply path 259 on the inside and concentric therewith. This inner annular flow path 261 serves for discharge of working fluid from within stage 241 (it is hereinbelow referred to as annular discharge path 261), and is connected to two discharge pipes 265 for discharge of working fluid to the outside. It is not essential that there should respectively be two supply pipes 263 and discharge pipes 265 and there could be one or three or more of these; however, from the point of view of thermal uniformity, preferably there are two or more arranged with practically equal pitch.

All of the descending flow paths 249A within stage 241 communicate with outer annular flow path 249C through inlet holes 269 respectively

provided in the upper end of annular wall 243, and communicate with annular discharge path 261 through outlet holes 271 respectively provided in the bottom of the lower end thereof. Also, all of the ascending flow paths 249B communicate with outer annular flow path 249C through inlet holes 269 respectively provided him in the lower end of annular wall 253, and communicate with annular discharge path 261 through outlet holes 271 respectively provided in the bottom of the upper end thereof. Inlet holes 269 and outlet holes 271 are arranged alternately along the entire peripheral region (circular flow path) of the ascending and descending flow paths 249A and 249B.

Stage 241 described above may be manufactured using material of good thermal conductivity, such as aluminum or copper alloy.

With a stage 241 constructed as above, as shown by the arrows in the two descending flow paths 249A and ascending flow paths 249B which are shown by way of example in Figure 17, the working fluid enters all of the descending and ascending flow paths 249A and 249B through all of the inlet holes 267 of annual wall 253 from annular flow path 249C at the peripheral region of the stage, and flows, within these flow paths 249A, 249B, from below to above and from above to below, until it issues outside the stage from outlet holes 271 at the peripheral region of the stage. In this process, heat exchange takes place between the working fluid and stage 241, causing the temperature of the working fluid to change. However, since the inlet holes 269 and outlet holes 271 for the working fluid are located at the peripheral region of stage 241 and the large

number of descending flow paths 249 A and ascending flow paths 249 B are alternately arranged so that the working fluid flows backwards and forwards, local temperature differences of stage 241 are moderated, and the temperature of stage 241 as a whole is efficiently equalized. In particular, the region where best temperature equalization is achieved is the circular flow path region (ascending and descending flow paths 249A and 249B) rather than the annular discharge path 261 of stage 241, so it is preferable to design the diameter of stage 241 sufficiently larger than the diameter of semiconductor wafer 245, so that semiconductor wafer 245 is placed above this inner region.

Figure 19 is a plan cross-sectional view sectioned along a horizontal plane of the stage of a substrate temperature control device according to a tenth embodiment of the present invention.

Stage 281 has overall a flat disc shape; as in the preceding embodiments, a substrate to be treated, for example a semiconductor wafer, is placed on its upper surface, small projections on the upper surface of the stage holding the semiconductor wafer separated by a gap of fixed width from the upper surface of the stage.

Stage 281 is constituted as a container having in its interior a cavity 289 which extends by more than the region directly below the semiconductor wafer, the cavity 289 therein being employed as a flow path for flow of the working fluid. This cavity (flow path) 289 is divided by an annular wall 293 arranged concentrically with stage peripheral side wall 291 and having a diameter somewhat smaller than that of side wall 291

into an annular flow path on the outside of this annular wall 293 (hereinbelow referred to as the outer annular flow path) 289A and an inner circular flow path 289B. Within circular flow path 289 B, there are erected innumerable pin-shaped fins 295 over the entire region; these pin-shaped fins 295 contribute to heat exchange with the working fluid.

Stage 281 is provided, at a single location of its peripheral region, with a supply section 297 for supplying working fluid into stage 281; this supply section 297 is connected to a supply pipe 301 which supplies working fluid from outside, and communicates with external annular flow path 289A. Also, at a location of the stage periphery that is symmetrical with that of supply section 297 with regard to the stage center, there is provided a drain section 299 for discharging working fluid from the interior of stage 281, this drain section 299 being connected to a discharge pipe 303 that discharges working fluid to the outside. Drain section 299 is of wider aperture than the supply section 297 in order to facilitate collection of the working fluid. A large number of inlet holes 297 are provided at practically equal pitch in annular wall 293 that partitions outer annular flow path 289A and circular flow path 289B. Also, the part of annular wall 293 facing drain section 299 is cut away to form an outlet hole 307.

Stage 281 described above may be constructed using material of good thermal conductivity, such as aluminum or copper alloy.

With a stage 281 constructed as above, as shown by the arrows in Figure 19, working fluid enters from supply section 297 into outer annular

flow path 289A of the peripheral region of the stage, and flows from outer annular flow path 289A through most of the inlet holes 305 of annular wall 293 into circular flow path 289B in the direction towards the central region, flowing from the periphery towards the center and from above to below within circular flow path 289B, until it finally issues at drain section 299 from outlet hole 307 in the peripheral region of the stage and is discharged to outside the stage. In this process, heat exchange takes place between the working fluid and stage 281, causing the temperature of the working fluid to change. However, since the working fluid flows into circular flow path 289B in mutually different directions from a large number of inlet holes 305 arranged in the peripheral region of stage 281, and innumerable fins 295 within circular flow path 289B disrupt and stir the flow of working fluid, local temperature differences of stage 281 are moderated, causing the temperature of stage 281 as a whole to be efficiently equalized. In particular, the region where best temperature equalization is achieved is the region of circular flow path 289B, so it is preferable to design the diameter of stage 281 sufficiently larger than the diameter of the semiconductor wafer, so that the semiconductor wafer is placed above this region of circular flow path 289B.

It should be noted that, in the stage 281 shown in Figure 19, of the large number of inlet holes 305 around the periphery of the circular flow path 289B, those inlet holes 305 that are positioned close to drain section 299 i.e. on the downstream side may actually function as outlet holes for working fluid issuing from circular flow path 289B into outer annular flow

path 289A, instead of as inlet holes. Even though this is the case, since the flow of working fluid within circular flow path 289 B is complicated in that it flows in different directions from the large number of inlet holes 305 on the upstream side, is stirred and disrupted by the large number of fins 295, until it issues in different directions from the large number of outlet holes 305 on the downstream side, excellent thermal uniformity is still obtained. Also, by providing a block or throttling to prevent or restrict passage of working fluid at a position within outer annular flow path 289A somewhat offset towards the downstream side, it can be arranged to make the inflow of working fluid into circular flow path 289 B more vigorous in inlet holes 305 upstream of this position and to positively utilize the inlet holes 305 on the downstream side of this position as outlet holes rather than as inlet holes. Also, provision of annular wall 293 referred to above may be dispensed with.

Figure 20 is a perspective view illustrating the stage of a substrate temperature control device according to an eleventh embodiment of the present invention.

Stage 311 is constituted of a flat disc-shaped container 313 in accordance with the principles of the present invention and a flat disc-shaped heat pipe 315 joined to the upper surface of this container 313. Container 313 may have a construction identical with that of any of the stages of for example Figure 14 to Figure 19. On the upper surface of heat pipe 315, there are provided small projections 317 for supporting the

semiconductor wafer. Even better thermal uniformity may be expected, thanks to the high thermal conduction action of heat pipe 315.

Figure 21 is a perspective view illustrating a stage of a substrate temperature control device according to a twelfth embodiment of the present invention.

Stage 319 is constituted of a flat disc-shaped container 321 in accordance with the principles of the present invention and a film-shaped electric heating wire heater 323 that is stuck on to the upper surface of this container 321. Container 321 may have the same construction as any of the stages illustrated for example in Figure 14 ~ Figure 19. On the upper surface of container 321, there are provided small projections 325 for supporting the semiconductor wafer. Temperature irregularities of container 321 that cannot be fully evened out simply using the working fluid can be compensated by electric heating wire heater 323, enabling even better thermal uniformity to be achieved. Electric heating wire heater 323 could be provided on the under-surface of container 321 rather than its upper surface.

Figure 22 is a cross sectional view illustrating a stage of a substrate temperature control device according to a thirteenth embodiment of the present invention.

Stage 327 comprises a flat disc-shaped container 329 in accordance with the principles of the present invention, and film-shaped electric heating wire heaters 331 and 333 that are stuck onto the upper surface and lower surface of this container 329. Container 329 may have a

construction identical with any of the stages illustrated in for example Figure 14 ~ Figure 19. Small projections 339 for supporting semiconductor wafer 337 are provided on the upper surface of container 329. Thanks to the presence of electric heating wire heaters 331, 333 on both the upper and lower surfaces of container 329, the temperature above and below stage 327 becomes uniform and distortion due to thermal expansion of stage 327 during abrupt temperature changes such as in particular on changeover between cooling and heating can be suppressed and the gap between stage 327 and semiconductor wafer 337 maintained uniform, thereby enabling even better thermal uniformity to be achieved.

Figure 23 is a plan cross-sectional view of two containers constituting the stage of a substrate temperature control device according to a fourteenth embodiment of the present invention. Figure 24 is a cross sectional view of this stage along the line D - D of Figure 23.

Stage 341 is constituted by joining two flat disc-shaped containers 343, 345 having a flat cross-sectional structure as shown in Figure 23 one on top of the other. Each of the two containers 343, 345 are provided in their interiors with a large number of mutually parallel elongate small flow paths 347, 349 in which working fluid flows in the same direction from a peripheral region on one side of one radius to a peripheral region on the other side. Also, the two containers 343, 345 are mutually joined in an attitude such that their mutual flow directions are opposite. Excellent thermal uniformity is obtained, since the temperature difference produced between the upstream side and downstream side of one of the containers

343 is compensated by the temperature difference produced between the upstream side and downstream side of the other container 345.

Figure 25 is a cross-sectional view illustrating a stage of a substrate temperature control device according to a fifteenth embodiment of the present invention.

Stage 351 has basically the same construction as the stage shown in for example Figure 19, but, throughout the circular flow path of the interior, instead of the pin-shaped fins shown in Figure 19, is packed with a cotton-like or gauze-like fiber body 353 made of aluminum or copper alloy which contributes to the heat exchange effect with the working fluid.

Figure 26 is a perspective view of a container constituting a stage of a substrate temperature control device according to a sixteenth embodiment of the present invention; Figure 27 is a cross sectional view along the line A - A of Figure 26.

Container 403 constituting stage 401 is a single flat disc of for example diameter 5 to 100 cm and thickness 0.3 to 5 cm. This container 403 comprises a fluid inlet 411 and 413 at the ends on opposite sides of the peripheral region, and comprises, within a cavity 405 for the passage of working fluid, a large number of ribs (or fins) 407 joined to the bottom wall and ceiling wall for creating turbulence, and three guide walls 409a, 409b, 409c. Two guide walls 409a, 409b are respectively straight and arranged in mutually parallel fashion, forming a flow path (hereinbelow called the central flow path) 415 whereby fluid from inlet 411 flows through the middle of cavity 403 in the direction of outlet 413. Central flow path 415

starts from inlet 411 and terminates in a position at about the middle of the center of cavity 403 and outlet 413. The other guide wall 403c is of approximately U shape, having a plurality of angles (for example three); it is arranged such that the fluid issuing from central flow path 415 is bent backwards by the recess of the U shape, and forms two flow paths (hereinbelow referred to as intermediate flow paths) 417a, 417b whereby the fluid flows at the outside of central flow path 415 in the opposite direction to central flow path 415. Intermediate flow paths 417a, 417b terminate in the vicinity of the periphery of container 3. The fluid issuing from intermediate flow paths 417a, 417b is again bent back and flows through outer flow paths 419a, 419b along the peripheral region of container 403 until it issues from outlet 413. The widths of central flow path 415, intermediate flow paths 417a, 417b and outer flow paths 419a, 419b are set such that the flow speeds in all flow paths are equal.

In this embodiment, if there were no guide walls 409a, 409b, 409c, there would be a difference between the flow speed flowing through the center of cavity 405 and the flow speed flowing on both sides thereof, which would produce an appreciable unevenness of temperature distribution of the upper surface of container 403. However, thanks to the arrangement of guide walls 409a, 409b, 409c as illustrated, the fluid flows around the entire cavity 405 with a practically uniform flow speed, meandering in respective Z shapes through the two half regions of cavity 405. In other words, by forcibly guiding the flow in the center of cavity 405 to both sides thereof (or, if aperture 413 is the inlet, forcibly guiding the

flow at the periphery of cavity 405 into the center), the flow speed throughout the entire cavity is made uniform, and thermal uniformity is increased. Also, thermal uniformity is further raised by the turbulence produced by the large number of ribs 407. Also, since the fluid outlet and inlet 411, 413 are provided at the periphery of container 403, the temperature distributions at the fluid outlet and inlet 411, 413 cannot easily influence the substrate; this also contributes to thermal uniformity. Also, since the flow paths can be freely formed simply by partitioning cavity 405 by guide walls 409a, 409b, 409c, manufacture can be easily accomplished. Also, since the meandering of the fluid passage has a simple Z shape, the pressure loss is small.

Various variations of the layout of guide walls 409a, 409b, 409c within cavity 405 may be considered. For example, three variations are illustrated in Figure 28, 29 and 30.

In the modification shown in Figure 28, bypass holes 423a, 423b, and 423c are provided in guide walls 409a, 409b, 409c in order to further improve the circulation of fluid. Bypass holes 423a, 423b, and 423c are provided in the vicinity of locations 424a, 424b, 424c where the fluid is bent back, so as to eliminate stagnation of fluid arising in the vicinity. Specifically, bypass holes 423a, 423b, 423c are provided in guide walls 409a and 409b in the vicinity of bending-back locations 424a, 424b of the outlets of intermediate flow paths 417a and 417b, so that some of the fluid within central flow path 415 is blown back at the bending-back locations 424a, 424b. Also, a bypass hole 423c is provided in guide wall 403c in the

vicinity of the bending-back location 424c of the outlet of central flow path 415, so that fluid that has stagnated at this bending-back vocation 424c can escape in the direction of outlet 413. In this way, the fluid can be more uniformly circulated through the cavity 421, thereby further improving thermal uniformity. A plurality of bypass holes 423a, 423b, 423c may be provided in guide walls 409a, 409b, 409c.

In the modified example shown in Figure 29, a U-shaped guide wall 427 is employed having a surface that is smoothly curved along the flow lines. By means of this guide wall 427, fluid can smoothly circulate through cavity 425.

In the modified example illustrated in Figure 30, all of the guide walls 431, 433, 427 have surfaces that are smoothly curved along the flow lines. Thanks to this construction, the fluid can smoothly circulate through cavity 429.

Although, in the description given above, container aperture 411 was used as the inlet and aperture 413 was used as the outlet, it would contrariwise be possible to employ aperture 413 as the inlet and aperture 411 as the outlet. However, if aperture 413 is employed as the inlet, the fluid entering the cavity immediately collides with guide wall 409c (or 427), so the temperature change of guide wall 409c (or 427) becomes large, with the possibility of an adverse effect on thermal uniformity. In contrast, if aperture 411 is used as the inlet, the fluid entering the cavity only strikes guide wall 409c after flowing to a position beyond the center of the cavity, so the temperature change of guide wall 409c can be made comparatively

small. It should be noted that the number of inlets and outlets of the container is not restricted to one.

Figure 31 is a plan cross-sectional view of a container constituting the stage of a substrate temperature control device according to a seventeenth embodiment of the present invention.

Container 437 constituting stage 435 is an approximately circular flat plate, provided at one location on its periphery with a portion 436 extending somewhat outwards. In the bottom wall of this extension 436, there are provided two fluid inlets 439 and 441 and a single outlet 441 positioned between these (the inlets and outlets could be interchanged). In the cavity 447 through which the fluid passes, there are erected a large number of pin-shaped fins (or ribs) 449 to create turbulence. Furthermore, three guide walls 451a, 451b, and 451c are provided within cavity 447. The two outside guide walls 451a, 451b form two flow paths 454a, 454b that guide the fluid from inlets 439 and 441 respectively along the periphery of container 437 to a location 453 on the opposite side to the fluid inlets and outlets, and a flow path 454c that guides the fluid that merges at this location 453 through the central region of cavity 447 to a location nearer outlet 443. Third guide wall 451c has an approximate U shape and forms flow paths 454d, 454e whereby fluid issuing from flow path 454c is bent back in the vicinity of outlet 443 so as to flow in the opposite direction, and flow paths 454f, 454g, and 454h whereby this fluid that has thus been bent back is bent back once more after striking guide walls 451a and 451b and made to flow to outlet 443. The width of flow

passages 454a ~ 454h is set such that fluid flows through the entire cavity with an even flow speed. Reference numerals 445a, 445b, 445c are through-holes for passage of pins (not shown) for raising and lowering a substrate placed at the upper surface of stage 435.

With this embodiment, thanks to guide walls 451 and 454, the fluid is made to circulate throughout the cavity 447, meandering therethrough with a practically even flow speed. In other words, thermal uniformity can be improved by forcibly bending back the fluid that flows along the periphery of cavity 447 so that it is made to flow through the center thereof with uniform flow speed, and forcibly bending back the fluid that flows through the middle of cavity 447 so that it flows with uniform flow speed at both sides. Thermal uniformity is further improved by the turbulence produced by the large number of fins 449. Also, by providing fluid inlets 439 and 441 and outlet 443 at the same location, the piping can be collected in a single location, thereby facilitating the provision of the piping.

Figure 32 shows a modified example of the embodiment of Figure 31.

In this embodiment, auxiliary guide walls 460a - 460d are arranged between guide walls 451a, 451b, and 451c. The flow of fluid can be optimized by suitable setting of the number, shape and arrangement of these guide walls 451a - 451c and 460a - 460d.

Figure 33 is a cross-sectional view of a container constituting a stage of a substrate temperature control device according to an eighteenth embodiment of the present invention.

For the container 503 that constitutes stage 501, any of the containers employed in for example the first embodiment to the seventeenth embodiment can be employed. Overall, this container 503 is constructed substantially vertically symmetrically, with the sheet-shaped thin-film heaters 505a and 505b shown in Figure 1 joined to its upper surface 503A and lower surface 503B. Electric heating wire sheets 505a and 505b have a very good heating effect, since they approach the wafer, not shown, most closely. These electric heating wire sheets 505a, 505b could be joined to only either one of upper surface 503A or lower surface 503B. However, by joining these to both surfaces as shown, temperature differences between the upper surface and under-surface of stage 501 can be substantially eliminated, thereby making it possible to prevent thermal deformation of the stage produced by such temperature differences. Also, from this point of view, it is desirable that fluid inlet 511 and outlet 513 should be provided at opposite ends of the container peripheral region, as shown in the drawing. In the cavity 525 shown in this Figure, a large number of fins (or ribs) 507 are arranged; guide walls for circulating the working fluid as shown in Figure 27 to 32 may of course be provided.

Figure 34 is a cross sectional view of a container constituting a stage of a substrate temperature control device according to a nineteenth embodiment of the present invention.

For the container 529 constituting this stage 509, any of the containers employed in the first embodiment to the seventeenth embodiment, as in the case of Figure 33 for example, may be employed;

the container as a whole is substantially symmetric vertically. In the middle of cavity 531 within container 529, there is provided a heater plate 533 parallel to the upper surface and lower surface of container 529. By means of this heater plate 533, cavity 531 is divided into two layers, thereby constituting cavity 531a on the side of the upper surface and cavity 531b on the side of the under-surface. The same fluid flows in each of these cavities 531a and 531b. Inlets 535a, 535b that supply fluid to each of the cavities 531a, 531b, and outlets 537a, 537b that discharge fluid from each of the cavities 531a, 531b are provided at opposite ends of the periphery of container 529. Inlets 535a, 535b and outlets 537a, 537b are mutually arranged in a vertically symmetric manner.

Heater plate 533 is utilized for heating of the substrate that is carried (not shown), or for temperature control of the fluid flowing through cavities 531a, 531b, and has electric heating wire heaters 539 embedded within it throughout its interior. A plurality of these heater plates 533 may be provided, so long as they divide the volume of cavity 531 equally or, in other words, so long as the layout of the interior of container 529 is vertically symmetric. Heater plate 533 may be provided with apertures (not shown) whereby fluid flowing over its upper surface and lower surface can mutually pass back and forth.

Thin-film sheets 505a, 505b shown in Figure 33 may be joined to the upper surface and under-surface of this container 529. Also, the functions of inlets 535a, 535b and outlets 537a and 537b may be interchanged provided they are mutually vertically symmetrical. For example, inlet

535b of cavity 531b may be made an outlet, while an outlet 537b may be made an inlet. By doing this, the directions of the fluid flowing through cavity 531a on the upper surface side and through cavity 531b on the under-surface side are made mutually opposite, so the temperature distribution of container 529 as a whole can be expected to be made even more uniform.

In this embodiment, by preparing two containers for example as described above, a thin-film sheet 505 or heat plate 533 may be interposed between these.

Although several preferred embodiments of the present invention have been described above, these are merely examples given in explanation of the present invention, and there is no intention to restrict the scope of the present invention solely to these practical examples. The present invention can be put into practice in various other modes.